This Supplementary Material accompanies the article:

Till, C. B. (2025) "Magmatic trees: a method to compare processes between igneous systems", Volcanica, 8(1), pp. 135–157. doi: 10.30909/vol.08.01.135157.

Till (2025) should be cited if these materials are used.

Worksheet for Constructing a 'Magmatic Tree'

Overview

Magmatic trees are designed to only illustrate the *internal processes* operating in magmatic systems, which can be readily identified via the modern petrologic and geochemical study of igneous rocks. This worksheet walks step-by-step through the predominant internal processes thought to govern the formation and evolution of a magma or igneous rock and the basic petrologic or geochemical methods to identify each of these processes, which can be used to construct a basic magmatic tree. The presence or absence of a process in the tree for your rock or eruption of interest can be determined by answering the series of questions provided. A blank tree is provided on the last page of the worksheet, which you can fill in step-by-step as you complete the worksheet. The processes included in this worksheet and basic magmatic trees facilitate comparison between many igneous systems (or rocks). But trees can also be amended to include additional igneous processes, depending on the datasets available for the rock or igneous system of interest.

1. Mantle Melting

- Does the rock fall below the line with the equation, SiO_2= 6.4 (FeO*/MgO) + 42.8 illustrated in Figure S1 below? (*Miyashiro, 1974*)

- Does it contain primary (i.e., not the result of secondary alteration) hydrous minerals such as amphibole, biotite, or muscovite?

- Does any plagioclase in the rock have high Anorthite contents (or a K_D plagioclase-liquid Ca-Na >1.5?) (e.g., *Sisson & Grove, 1993*)

- Do melt inclusions from the rock contain > ~1 wt% H_2O?

If the answer to any of these questions is **yes**, then the rock likely originated via **flux melting** of the mantle (and/or assimilated a hydrous, calc-alkaline magma via crustal melting or mixing).

If the answer is **no**, it is more likely the rock originated via **decompression melting** of the asthenospheric mantle.

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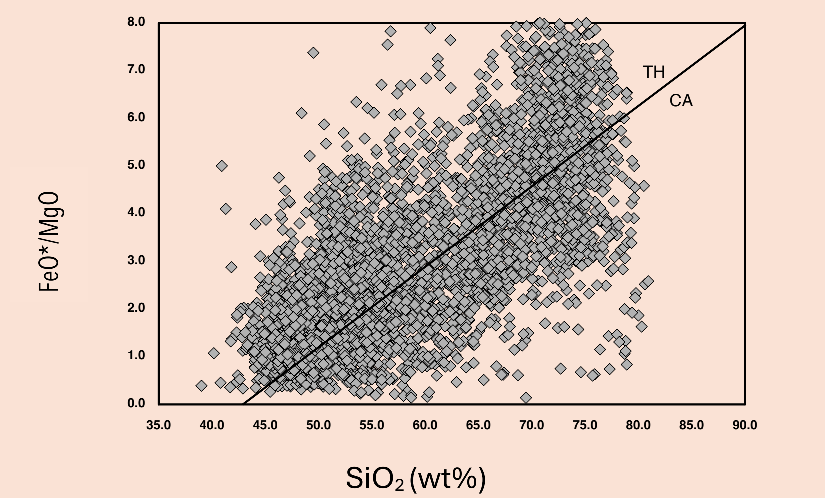

Figure S1. Miyashiro discrimination diagram illustrating the tholeiitic & calc-alkaline fields. Gray data points are a global composition of arc melt inclusions from GEOROC database (2014).

2. Mantle Transport

- Does mantle thermobarometry (e.g., *Till, 2017; Krein et al., 2021*) yield pressure-temperature conditions above the anhydrous mantle solidus?
- Are channels bounded by orthopyroxene or clinopyroxene evident in the host rock where the melt originated?
- Did the rock originate via decompression melting?

If the answer to any of these questions is **yes**, then the rock was likely transported via **channelized flow** in the mantle.

If the answer is **no**, it is more likely the rock was transported via reactive porous flow.

3. Crystallization

- Does the sample contain crystalline minerals?
- Does the sample have a bulk Mg# < 0.6-0.7,
  where Mg# = (MgO/40.311)/((MgO/40.311)+(FeO*/71.844)) with MgO & FeO in wt% and FeO*= all Fe is calculated as Fe^{2+}?

If the answer to any of these questions is **yes**, then the rock likely experienced a **reasonable amount of crystallization**.

- Did the rock originate via flux melting/contain H_2O, have SiO_2 contents >60 wt% and is it peraluminous (i.e., has an ASI index (molar Al/(2Ca+Na+K) > 1)?

If the answer to any of these questions is **yes**, then the rock likely experienced **high pressure (>~1 GPa) crystallization**, including abundant near-liquidus crystallization of calcic pyroxene (*Blatter et al., 2013; 2023*).

- Does the rock have HREE depletions, high Sr/Y, high Ce/Y, moderate Fe/Mg ± ^{230}Th excess?

If the answer to this question is **yes**, then the rock likely experienced **high pressure (>~1 GPa) garnet crystallization**. *(e.g., Jicha et al., 2009*)

4. Crustal Melting

Lower Crustal Melting

- Does the rock contain >60 wt% SiO_2 and an ASI index (molar Al/(2Ca+Na+K) < 1? *(Blatter et al., 2013; 2023)*
- Does the rock have ^{230}Th/^{238}U >1, high Sr/Y and high Ce/Y >1? *(Wende et al., 2015)*
- Do U-series isotopes show ^{230}Th-excesses (^{230}Th/^{238}U >1) and low Th/U?
- Do ^{87}Sr/^{86}Sr show correlations with Th isotopic compositions and exhibit values >~0.703-.704? (Klamath Mountains Pluton = 0.7035: *Barnes et al., 1992*; Trinity Ophiolite = 0.7065: *Brouxel & Lapierre, 1988*) (*e.g., Wende et al., 2015*)

If the answer to any of these questions is **yes**, then the rock likely incorporated **melts** of mafic lower crustal protoliths.

Upper Crustal Melting

- Do oxygen isotopes values (δ^{18}O) show:
  - variations between magmas with different bulk SiO2 contents (with the highest (δ^{18}O found in dacitic - rhyolitic magmas) (*e.g., Feeley et al., 2008*)?
  - disequilibrium between different types of minerals?
  - intra-crystalline zoning of $\geq$ 1-2 per mil?
  - zircon populations with different δ^{18}O values (*e.g., Bindeman et al., 2008*)?
- Do you U-Th isotopes reveal ^{238}U excesses? (*Ankney et al., 2013*)

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If the answer to any of these questions is **yes**, then the rock likely incorporated **melts** of silicic upper crustal protoliths with or without hydrothermal alteration.

5. Mixing

Does the rock contain:

- multiple populations of the same mineral (with different compositions) indicative of mixing (e.g., "four pyroxene andesites")?
- disequilibrium mineral assemblages (e.g., quartz & olivine)?
- evidence of mechanical mixing shortly before eruption including banded pumice, chemically zoned deposits, and/or mafic enclaves with crenulated (i.e., quenched) margins?

Does the geochemistry of different samples from the same eruption, or series of eruptions, create a straight line on a plot of two major element oxides? See Figure S2 below.

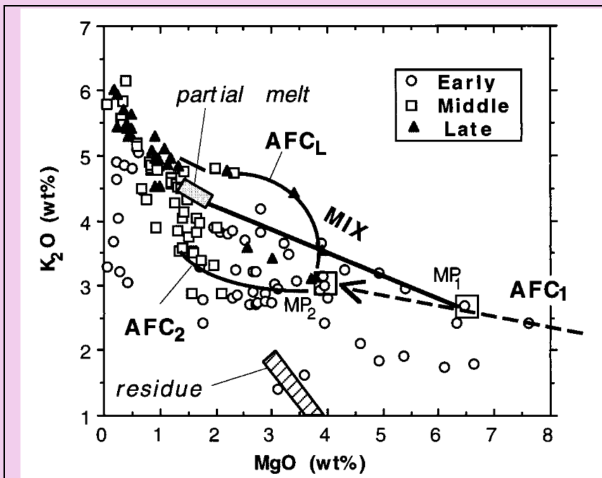

Figure S2. K_2O vs. MgO composition of ca. 35 Ma volcanic rocks from east-central Nevada and Utah from Grunder (1995). Mixing between mafic parental melts ('MP_1 & MP_2') and a crustal melt ('partial melt') produces magma compositions that plot along a straight line ('MIX'), whereas crystallization of the mafic parent magma 2 ('MP_2') produces the curved path labelled 'AFC_2'. Figure 3 from Grunder (1995).

If the answer to any of these questions is **yes**, then the rock likely experienced mixing between two distinct magma types.

6. Eruption Initiation Mechanism

If the rock experienced magma mixing, does it meet the criteria for mafic recharge or mafic or felsic rejuvenation (*e.g., Kent et al., 2023*)?

- **Mafic Recharg**e - Does the sample contain:
    - reversely zones crystals
    - disequilibrium mineral assemblages (e.g., quartz & olivine)

- multiple mineral populations indicative of mixing (e.g., "four pyroxene andesites")
- abundant quenched enclaves of contrasting composition,
- banded pumice
- and/or compositionally zoned eruptive deposits?

If the answer to any of these questions is **yes**, then the event that caused final ascent and cooling of the rock was likely **mafic recharge** (which is a type of magma mixing).

- **Mafic or Felsic Rejuvenation** – Does the sample contain:
  - Mineral rims similar or with subtle zoning in major element concentration but with higher concentrations of magmaphile major or trace elements (e.g., Ba, Ti, Mg in rhyolites, or Mg/Fe, La, in basalts) and/or records of higher temperatures than adjacent interior zones?
  - Evidence for disaggregation of crystal-rich mushes or cumulates such as glomerocrysts, strained crystals etc.?

If the answer to any of these questions is **yes**, then the event that caused the final ascent and cooling of the rock was likely **mafic or felsic rejuvenation** (a type of magma mixing).

If the rock did not experience magma mixing, does it meet the criteria for volatile accumulation?

- **Volatile Accumulation** – Does the sample contain:
  - Mineral rims with enrichments in elements likely to be partitioned into an exsolved volatile phase (e.g., Li) (*e.g., Kent et al., 2007*)?
  - Mineral rims exhibiting an increase in hydrous mineral and/or fluid inclusions?
  - An increase in volatile concentration recorded by melt inclusions with increasingly younger relative ages?

If the answer to any of these questions is **yes**, then the event that caused final cooling of the rock was likely **volatile accumulation** (also known as second boiling).

If the rock **does not meet the criteria for any of the internal eruption initiation mechanisms**, then it is possible the final ascent and cooling of the rock was caused by a **process or event external to the magmatic system,** such as glacial unloading, an earthquake or roof collapse.

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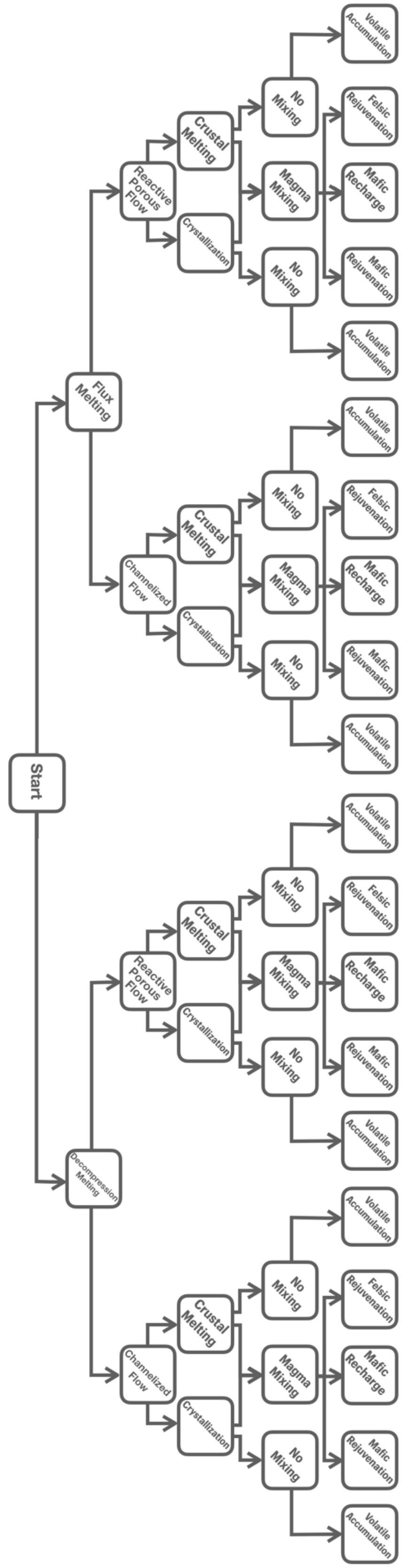

Figure S3. Blank basic magmatic tree to use with this worksheet. Fill in the nodes based on the answers to the provided questions to determine the key magmatic processes that were involved in the formation of a particular igneous rock or eruption.

Supplement to ***Magmatic Trees: A Method to Compare Processes Between Igneous Systems*** by C. Till (2025)

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